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ON THE EMBRYOLOGICAL BASIS OF HUMAN MORTALITY¹

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Read before the Academy, November 11, 1919

1. In order to get a clearer idea of the underlying biological factors in human mortality I have rearranged the 'causes of death' listed in the International Classification of the Causes of Death, which is the code used generally by vital statisticians, into a new classification on a biological basis. It is not possible with our present statistical material to make a completely and precisely logical classification, but I have endeavored to come as close to it as is possible. The underlying idea of this new classification is, as the first operation, to group all causes of death under the heads of the several organ systems of the body, the functional breakdown of which is the immediate or predominant cause of the cessation of life. All except a few of the statistically recognized causes of death in the International Classification can be assigned places in such a biologically grouped list. It has a sound logical foundation in the fact that, biologically considered, death results because some organ system, or group of organ systems, fails to continue its functions. Practically, the plan involves the reassignment of all of the several causes of death now grouped by vital statisticians under heading 'I. General diseases.' It also involves the re-distributing of causes of death now listed under the puerperal state, malformations, early infancy, and certain of those under external causes.

The headings finally decided upon for the new classification are as follows:

- I. Circulatory system, blood, and blood-forming organs
- II. Respiratory system
- III. Primary and secondary sex organs
- IV. Kidneys and related excretory organs
- V. Skeletal and muscular systems
- VI. Alimentary tract and associated organs concerned in metabolism
- VII. Nervous system and sense organs
- VIII. Skin
- IX. Endocrinal system
- X. All other causes of death

It should be emphasized that the underlying idea of this rearrangement of the causes of death is to put all those lethal entities together which bring about death because of the functional organic breakdown of the same general organ system. The cause of this functional breakdown may be anything whatever in the range of pathology. It may be due to bacterial infection; it may be due to trophic disturbances; it may be due to mechanical disturbances which prevent the continuation of normal function; or to any other cause whatsoever. In other words, the basis of the present classification is not that of pathological causation, but it is rather that of organological breakdown. We are now looking at the

TABLE 1
SHOWING THE RELATIVE IMPORTANCE OF DIFFERENT ORGAN SYSTEMS IN HUMAN MORTALITY

GROUP NUMBER	ORGAN SYSTEM	DEATH RATES PER 100,000			
		Registration area, U. S. A.		England and Wales, 1914	Sao Paulo, 1917
		1906-10	1901-05		
II	Respiratory system.....	395.7	460.5	420.2	417.5
VI	Alimentary tract and associated organs...	334.9	340.4	274.1	613.8
I	Circulatory system, blood.....	209.8	196.8	208.6	254.8
VII	Nervous system and sense organs.....	175.6	192.9	151.9	124.3
IV	Kidneys and related excretory organs.....	107.2	107.4	19.4	83.4
III	Primary and secondary sex organs.....	88.1	77.4	95.4	103.2
V	Skeletal and muscular system.....	12.6	13.7	18.2	6.8
VIII	Skin.....	10.1	13.3	12.0	7.9
IX	Endocrinal system.....	1.5	1.2	1.9	1.1
	Total death rate classifiable on a biological basis.....	1335.5	1403.6	1231.7	1612.8
X	All other causes of death.....	171.3	211.9	141.4	109.8

question of death from the standpoint of the pure biologist, who concerns himself not with what causes a cessation of function, but rather with what part of the organism ceases of function, and therefore causes death.

2. In table 1 the death rates per 100,000 are arranged in descending order of importance (for the United States Registration Area 1906-10) by organ systems. Four sets of data are used: (a) the United States Registration Area for the five years, 1906-10 inclusive; (b) the same, 1901-05; (c) England and Wales, 1914; and (d) Sao Paulo, Brazil, 1917.

3. The data show that in the United States, during the decade covered, more deaths resulted from the breakdown of the respiratory system than from the failure of any other organ system of the body. The same thing

is true of England and Wales. In Sao Paulo the alimentary tract takes first position, with the respiratory system a rather close second. The tremendous death rate in Sao Paulo chargeable to the alimentary tract is chiefly due to the relatively enormous number of deaths of infants under two from diarrhea and enteritis. Nothing approaching such a rate for this category as Sao Paulo shows is known in this country or England.

In all three localities studied the respiratory system and the alimentary tract together account for rather more than half of all the deaths biologically classifiable. These are the two organ systems which, while physically internal, come in contact directly at their surfaces with environmental entities (water, food, and air) with all their bacterial contamination. The only other organ system directly exposed to the environment is the skin. The alimentary canal and the lungs are, of course, in effect invaginated *surfaces* of the body. The mucous membranes which line them are far less resistant to environmental stresses, both physical and chemical, than is the skin with its protecting layers of stratified epithelium.

The organs concerned with the blood and its circulation stand third in importance in the mortality list. Biologically the blood, through its immunological mechanism constitutes the second line of defense which the body has against noxious invaders. The first line is the resistance of the outer cells of the skin and the lining epithelium of alimentary tract, lungs, and sexual and excretory organs. When invading organisms pass or break down these first two lines of defense the battle is then with the home guard, the cells of the organ systems which, like the industrial workers of a commonwealth, keep the body going as a whole functioning mechanism. Naturally it would be expected that the casualties would be far heavier in the first two defense lines (respiratory and alimentary systems, and blood and circulation) than in the home guard. Death rates when biologically classified bear out this expectation.

It is at first thought somewhat surprising that the breakdown of the nervous system is responsible for more deaths than that of the excretory system. When one bears in mind, however, the relative complexity of the two pieces of machinery, it is perceived that the relative position of the two in responsibility for mortality is what might be reasonably be expected.

In the United States the kidneys and related excretory organs are responsible for more deaths than the sex organs. This relation is reversed in England and Wales and in Sao Paulo. The difference is mainly

due, in the case of England, to two factors, premature birth and cancer. In Sao Paulo it is due to premature birth and syphilis.

In a broad sense the efforts of public health and hygiene have been directed against the affections comprised in the first two items in the table, respiratory system and alimentary tract. The figures in the first two columns for the two five year periods in the United States indicate roughly the rate of progress such measures are making, looking at the matter from a broad biological standpoint. In reference to the respi-

TABLE 2
SHOWING THE RELATIVE INFLUENCE OF THE PRIMARY GERM LAYERS IN HUMAN MORTALITY
(Items 64 and 65 charged to ectoderm)

LOCALITY	DEATH RATE PER 100,000 DUE TO FUNCTIONAL BREAKDOWN OF ORGANS EMBRYOLOGICALLY DEVELOPING FROM					
	Ectoderm	Per cent	Meso-derm	Per cent	Endo-derm	Per cent
United States Registration Area, 1906-10	191.1	14.3	425.2	31.8	719.6	53.9
United States Registration Area, 1901-05	210.6	15.0	407.1	29.0	786.2	56.0
England and Wales, 1914.....	177.1	14.4	374.0	30.3	681.5	55.3
Sao Paulo, 1917.....	134.9	8.4	468.0	29.0	1009.9	62.6

TABLE 3
SHOWING THE RELATIVE INFLUENCE OF THE PRIMARY GERM LAYERS IN HUMAN MORTALITY
(Items 64 and 65 charged to mesoderm)

LOCALITY	DEATH RATE PER 100,000 DUE TO FUNCTIONAL BREAKDOWN OF ORGANS EMBRYOLOGICALLY DEVELOPING FROM					
	Ectoderm	Per cent	Meso-derm	Per cent	Endo-derm	Per cent
United States Registration Area, 1906-10	116.9	8.7	499.4	37.4	719.6	53.9
United States Registration Area, 1901-05	137.3	9.8	480.4	34.2	786.2	56.0
England and Wales, 1914.....	107.9	6.7	443.2	36.0	681.5	55.3
Sao Paulo, 1917.....	101.3	6.3	501.6	31.1	1009.9	62.6

ratory system there was a decline of 14% in the death rate between the two periods. This is substantial. It is practically all accounted for in phthisis, lobar pneumonia, and bronchitis. For the alimentary tract the case is not so good—indeed, far worse. Between the two periods the death rate from this cause group fell only 1.8%.

4. The next step in the investigation was to arrange all the organologically classifiable death rates under the primary germ layers (ectoderm, mesoderm, and endoderm) from which the organs concerned developed embryologically. The results are set forth in tables 2 and 3, and in

figure 1. Tables 2 and 3 give upper and lower limiting values to the death rates chargeable to ectoderm and mesoderm. The difference between the two depends upon the placing of deaths due to cerebral hemorrhage and apoplexy, and to 'softening of the brain'. The discussion of the embryological and pathological problems involved cannot be given here by reason of lack of space. The complete paper must be consulted.



U.S. REGISTRATION AREA - 1906-10



U.S. REGISTRATION AREA - 1901-5



ENGLAND AND WALES - 1914



SAO PAULO - 1917

ENDODERM

MESODERM

ECTODERM

FIG. 1. DIAGRAM, SHOWING THE PERCENTAGES OF BIOLOGICALLY CLASSIFIABLE HUMAN MORTALITY RESULTING FROM BREAKDOWN OF ORGANS DEVELOPING FROM THE DIFFERENT GERM LAYERS

Upper bar of pair gives upper limit of mortality chargeable to ectoderm; lower bar gives lower limit of mortality chargeable to ectoderm.

The data of tables 2 and 3 are shown graphically in percentage form in figure 1.

The final results lead to a generalization of considerable interest and significance to the evolutionist. The figures show that in man, the highest product of organic evolution, about 57% of all the biologically classifiable deaths result from a breakdown and failure further to function

of organs arising from the endoderm in their embryological development while but from 8 to 13% can be regarded as a result of breakdown of organ systems arising from the ectoderm. The remaining 30 to 35% of the mortality results from failure of mesodermic organs. Taking a general view of comparative anatomy and embryology it is evident that in the evolutionary history through which man and the higher vertebrates have passed it is the ectoderm which has been most widely differentiated from its primitive condition, to the validity of which statement the central nervous system furnishes the most potent evidence. The endoderm has been least differentiated in the process of evolution, while the mesoderm occupies an intermediate position in this respect.

The results of this study add one more link to the already strong chain of evidence which indicates the highly important part played by innate constitutional biological factors as contrasted with environmental factors in the determination of the observed rates of human mortality. Here we have grouped human mortality into broad classes which rest upon a strictly biological basis. When this is done it is found that the proportionate subdivision of the mortality is strikingly similar in such widely dissimilar environments as the United States, England, and Southern Brazil. It is inconceivable that such congruent results would appear if the environment were the predominant factor in human mortality. This conclusion does not overlook the fact that in some diseases the environment, in a broad sense, is unquestionably the factor of greatest importance. Nor does it imply that every effort should not be used to measure in every case the precise relative influence of constitution or heredity as compared with environment in the natural history of particular diseases. This constitutes one of the most pressing and difficult problems of medical science.

¹ A complete account of this investigation will appear shortly in the *American Naturalist*. That paper must be consulted for detailed discussion of the intricate pathological and embryological points involved in the statistical treatment of the data in this investigation.